REBUTTAL EXPERT REPORT OF STEVE W. MARTIN, Ph.D.

Marcellin and Estate of Hollowell v. HP Inc., and Staples, Inc.

United States District Court, Western District of New York

This Rebuttal Report is submitted to supplement my prior report and to address issues raised in the expert reports submitted on behalf of Defendant HP.

I. EXTERNAL FIRE CAUSING THERMAL RUNAWAY REACTION

As discussed at length in my first report, "Thermal runaway" of a cell is an energetic failure mode and refers to the rapid self-heating of a cell arising from the exothermic chemical reaction of the highly oxidizing positive electrode and the highly reducing negative electrode. This process can begin at cell internal temperatures as low as 70 to 90°C (158 to 197 °F). Sorensen et al., (2024) have proposed a two-step process leading to thermal runaway of lithium ion battery cells. The first critical phase, which the authors refer to as Stage II, is when the cell internal temperature reaches a point that causes irreparable damage to the cell but complete destruction can still be avoided by proper cooling before the cell temperature reaches a critical temperature where thermal runaway begins. The authors demarcate the temperature range for Stage II to be from 117.6 °C to 198.5 °C (243 °F to 389.3°F). Once the cell temperature reaches Stage III at approximately 200°C (390°F), complete destruction of the cell is unavoidable because the separator micropores increase in size to allow a hard short between the anode and the cathode, allowing all internal stored energy to be completely discharged.

Dr. Horn opines that the thermal runaway reaction that occurred in the cells of the subject HP laptop battery pack was caused not by any of the well-recognized and very common internal causes (e.g. overcharge, overvoltage, overtemperature) but from the external heating of the battery pack from a preexisting fire of unknown origin. (Horn, p. 16). Dr. Horn provides no evidentiary support for his speculation that the battery pack was externally heated sufficiently to

cause thermal runaway other than a reference to Ms. Marcellin's testimony which is addressed below. However, his speculation would require the laptop to have been exposed to extremely high temperatures for a length of time that is unsupported by any of the physical evidence in this case.

Larsson et al., (2018) performed a detailed study exposing standard lithium-ion battery cells of the type utilized for laptop computer battery packs (such as the subject laptop) to external heating to determine the internal temperatures and times at that temperature required for cell thermal runaway to occur and whether there were differences in the onset and character of thermal runaway reactions based upon the condition of the battery cells. These authors purposely aged battery cells by exposing some of the cells to multiple cycles (100-300 charge to complete discharge cycles) and while others were stored at excessive temperatures (60°C for 10 months) to determine if either method of aging affected the temperature at which thermal runaway failure began (Stage II above) or the extent of the failure reaction (flares, sparks, jet flames, gas explosions). To conduct this experiment, the cells were placed inside an oven heated to 300°C (572°F) until thermal runaway occurred.

The results of these experiments by Larsson et al. are summarized in Tables 3 and 4 of the study. The time at which thermal runaway and major venting occurred was surprisingly consistent for all tested cells independent of their ageing histories, ranging from a minimum time of 60.39 minutes for one of the cells that had been cycled 200 times before the experiment, to a maximum of 72.04 minutes for a cell that was fully discharged and had been stored at high temperature for 10 months. The other twelve cells, including those not subjected to any aging, fell inside these two extremes. (Table 3). The internal cell temperatures at which Stage II

thermal runaway occurred for all 14 cells was also remarkably similar. This Stage II reaction occurred between 188°C and 205°C (370-401°F) in all cells. (Table 4).

Applying these data to Dr. Horn's hypothesis, which assumes that a thermal layer from a preexisting fire of unknown origin externally heated the battery pack cells, would require a thermal layer temperature in excess of 300°C (572°F) for a period of over an hour for this external fire source to have provoked the thermal runaway reaction that all experts agree occurred in multiple cells of the subject laptop battery pack. To incorporate the data from Larsson et al. (2014) into Dr. Horn's speculation that the battery cells were provoked into thermal runaway by an external heat source, the thermal layer temperature would need to be higher than 300 ºC and the duration of the exposure of the laptop to this thermal layer would have to be longer because the cells in the Larsson study were inserted directly into the 300°C oven without any external wrappings or protection. Thus, the heat from the ovens in the Larsson experiments was transferred directly without any thermal barrier between the heat source (the internal oven temperature) and the bare battery cell. In the case of the battery pack in the subject laptop, there are at least three thermal barriers between any speculated external heat source and the battery cells that would have insulated the battery cells from the speculated external heat source. First, the battery cells were encased in a plastic wrapping. Next, the plastic wrapped cells were enclosed in a plastic case. Finally, the plastic case of the battery pack was then inserted into the bottom of the laptop that was sitting on the flat surface of the wooden desktop. These three thermal barriers would have acted to insulate the battery cells from the speculated external heat source making heating less efficient than in the oven in the Larsson study. At each thermal barrier, the temperature would have dropped and the temperature would have been cooler than the preceding layer. Hence, in order for the cells to have reached the well documented internal

thermal runaway temperature of about 200 ºC, the external temperature would need to be well above 300 ºC.

Likewise, the time to thermal runaway would also have been longer in the batteries of the subject laptop than that in the Larsson study because all of the thermal barriers described above have finite thermal conductivities. This means that not only must the external temperature be hotter to achieve the same internal thermal runaway temperature, but the time that it would have taken for the cells to rise to the thermal runaway temperature would have been longer because the heat flow from the hot external temperature, the speculated fire, would have been smaller due to the thermal insulation provided by the three thermal layers described above. All of these factors would required a hotter external temperature for the cells in the battery pack to reach thermal runaway and a longer time to reach thermal runaway than found in the Larsson study.

Mr. Karasinski's rebuttal report further demonstrates that the thermal layer never reached the height of the laptop even at the maximum intensity of this fire, which would have been reached long after the thermal runaway reaction had already occurred. Measurements taken from 3D camera photographs demonstrate the lowest point reached by the thermal layer in the room where the fire began and the laptop was located was three feet, two inches above the floor. The height of the desktop in the armoire on which the subject laptop was located was only two feet, two inches above the floor. (See Figures 1 & 2 below). Thus, the thermal layer speculated by Dr. Horn as the cause of thermal runaway in the laptop battery pack never reached the level of the laptop and could not have provided a sufficient heat source to independently provoke thermal runaway reactions in multiple battery cells.

Figure 1 - Showing measured heights of lowest point reached by thermal layer (from Karasinski rebuttal report).

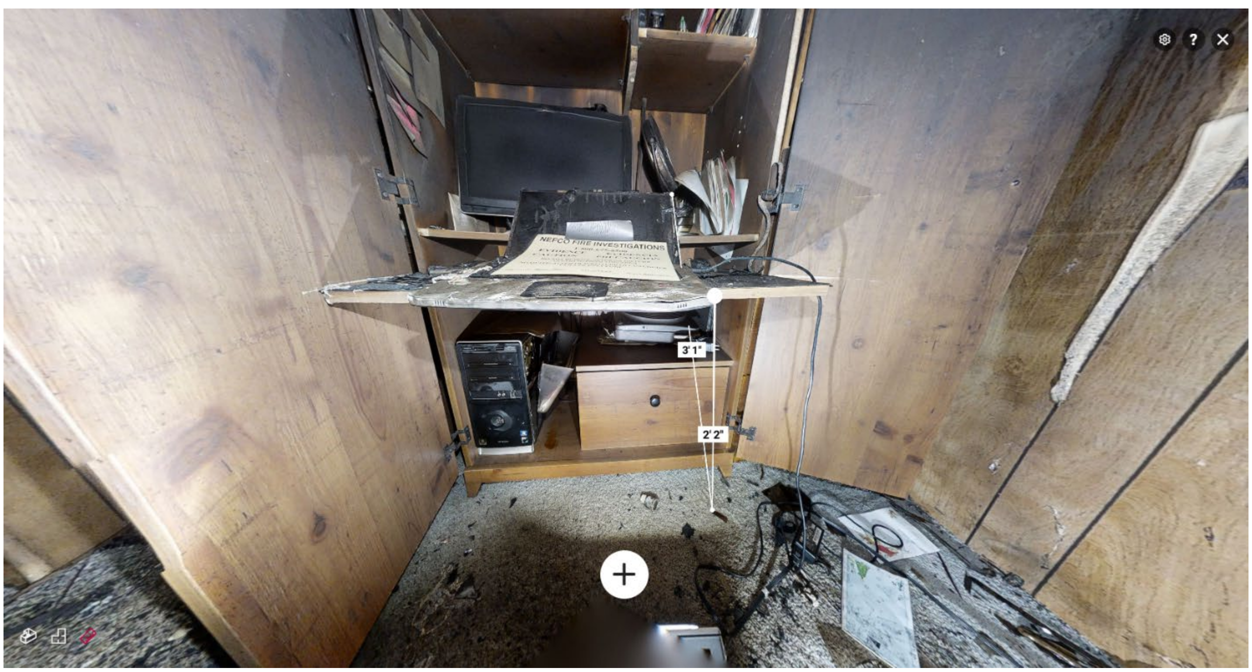


Figure 2 - Showing measured height of desktop where laptop was located (from Karasinski rebuttal report).

Fully consistent with these measurements, my examination of the subject laptop demonstrates there was no significant evidence of extreme temperature heating of the casing of

the laptop. Had the whole of the laptop been exposed to the extreme temperatures well above 300 ºC from the large room-wide thermal layer coming down from the ceiling as required in the Horn speculation and required for the insulated battery cells to reach the thermal runaway temperature, the many plastic parts of laptop with a softening point of only about 200 ºC (392°F) would have been significantly melted, deformed, and charred.

Indeed, the speculation that an external heat source caused the overheating of the battery cells is further refuted by examination of the bottom of the laptop in the area where the battery pack was located. Figure 4 is a photograph of the bottom of the laptop taken by the author that clearly shows a majority of the compartment where the battery pack was located completely melted and burned away. However, areas only slightly away from this region are essentially undamaged. The speculation of the Horn report is that a room-wide thermal layer descended upon the laptop from the ceiling and caused the laptop to get hot enough to cause the batteries thermally insulated inside the laptop and battery pack to reach thermal runaway. My Figure 4 clearly refutes this speculation. The thermally exposed left and right sides of the laptop are essentially undamaged. Had the speculated thermal layer descended upon the whole of the laptop it certainly would have heated the sides of the laptop to the extremely high temperature required to cause the cells inside the battery pack to reach thermal runaway. This is not seen in the evidence of the subject laptop. The sides of the laptop that would have experienced the full impact of the speculated thermal layer are undamaged.

Rather, consistent with the whole body of actual evidence and testimony is that only the area of the battery pack definitively demonstrates exposure to temperatures consistent with the thermal runaway inside the cells. Therefore, the thermal runaway reaction began in the cells and

the extreme temperatures within the cells caused total destruction of the bottom of the laptop in this region.

Figure 4 – Photo of the bottom of the subject laptop (source S. W. Martin).

Instead of relying on any physical evidence of the thermal layer created by the speculated fire from an unknown source reaching the laptop level or evidence any laptop components other than those close to the battery pack being exposed to extreme temperatures, Dr. Horn bases his speculation entirely on the timing of the thermal runaway reaction, which he extrapolates from the testimony of Carol Marcellin:

> In my experience, thermal runaway of an 18650 battery cell completes in seconds once it has started. Based on [the description of events given by Plaintiff Carol Marcellin] the fire had progressed sufficiently to trip the fire alarm before Ms. Marcellin entered the room. Ms. Marcellin subsequently observed "fireballs" from the notebook and the fire "dropping from the ceiling". If this is when the cell thermal runaway events were occurring, then this would have been well after the fire had started.

[Horn Report, p. 35].

The quoted and sworn testimony from Ms. Carol Marcellin does not support Dr. Horn's speculation that the source of the fire must have been something other than thermal runaway of the cells in the laptop battery pack. Initially, thermal runaway reactions in a specific cell progress over a period of time measured in minutes and do not progress to completion in a matter of a few seconds. The venting of flammable gases and eventual ejection of cell windings in the course of a thermal runaway reaction can occur for 30 to 50 seconds per cell and can last as long as multiple minutes, depending on the size of the cell and the configuration of the internal materials. Moreover, as stated in my prior report: "When these processes occur in a single cell in a multi-cell pack configuration, they are likely to propagate to other adjacent cells in the pack by way of various heat transfer mechanisms including direct case-to-case contact, impingement of hot vent gasses or impingement of flaming vent gases." (p. 11).

Thus, when the thermal runaway reaction begins in a single cell, which is most common, the heat from that reaction will spread to adjacent cells first and to more distant cells thereafter. When each of those cells reaches sufficient temperatures to begin its own thermal runaway reaction, the same sequence of events will occur. The time sequence over which multiple cells in a battery pack containing 18650 battery cells that sequentially experience thermal runaway can therefore last for many minutes depending on which cell in the battery pack begins the chain reaction.

This chain of events not only explains what Ms. Marcellin witnessed, but is entirely consistent with the remnants of the 6 battery cells found in the room after the fire. Two of the cells were found to have violently ruptured from an internal explosion. Two of the cell casings were intact, but the contents of these cells had burned out completely. The remaining two cells

were found to be largely intact. Figures 5, 6, and 7 show pictures of these three sets of cells respectively.

Figure 5 – Photographs of two of the six cells in the subject laptop that remained largely intact during the fire.

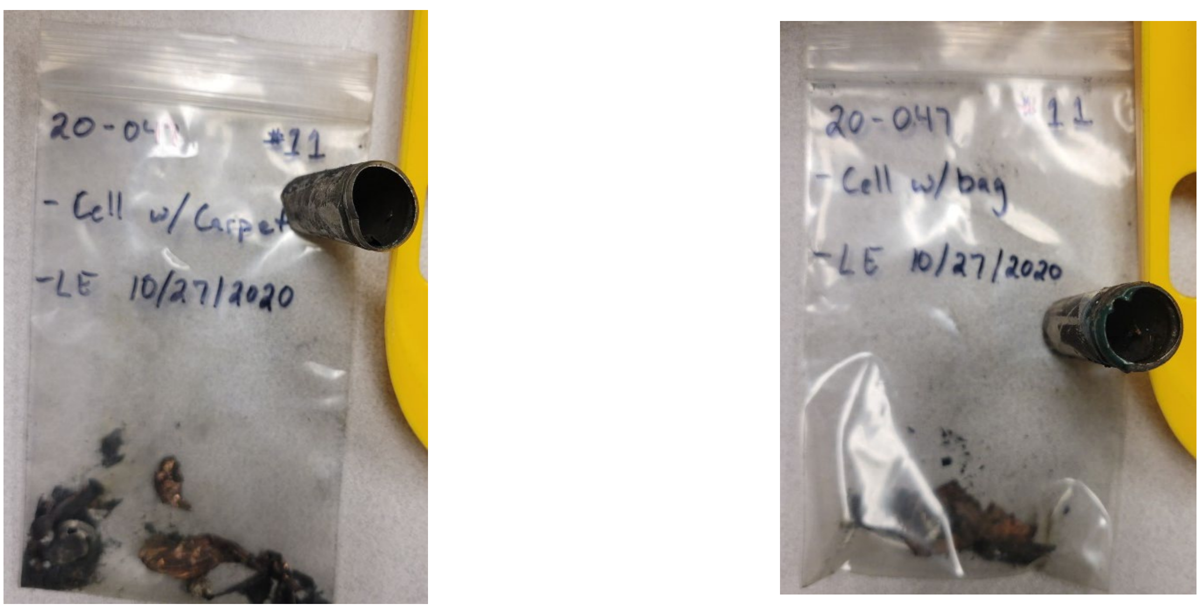
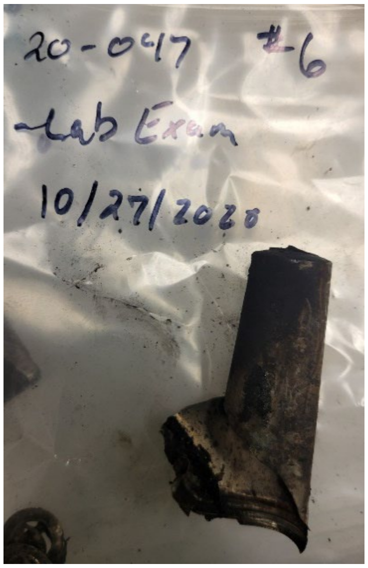


Figure 6 – Photographs of two of the six cells in the subject laptop that burned to essentially to completion and were empty during the fire.



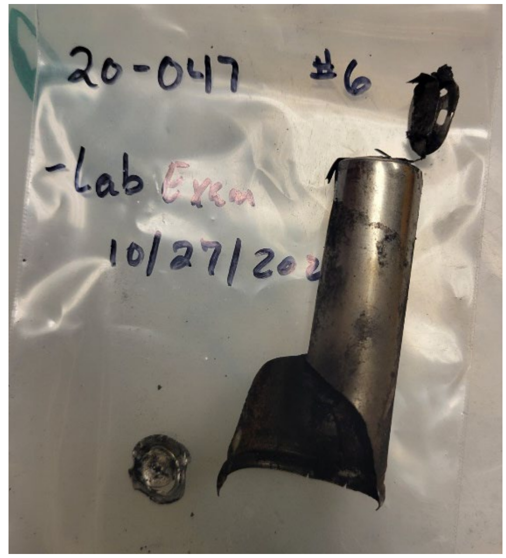


Figure 5 – Photographs of two of the six cells in the subject laptop that exploded during the fire.

As demonstrated in Figure 4 above, the progression in the extent of damage to the six cells, largely intact with little to no fire, complete fire burnout but with no explosion, and finally cell explosion and rupture, matches the pattern of the fire damage to the bottom of the laptop where the battery pack was inserted. Proceeding from left to right in Figure 4, the far left area of the battery pack is largely unburned and intact, whereas the far right side of the battery pack area is largely destroyed and burned away.

These results are consistent with a successive chain reaction of events that started with a smaller number of cells reaching thermal runaway leading to other immediately adjacent cells heating up and going into thermal runaway and more distant cells being too far away from the heat created by the first cell's failure to be induced into thermal runaway themselves.

Such a successive progression is further consistent with the timeline of events as testified by Ms. Marcellin. This progression would take more time than the few seconds as speculated by

Dr. Horn and as such would be consistent with the longer period of time as described by Ms. Marcellin.

Ms. Marcellin's testimony of smelling smoke and then visually witnessing smoke in the office and projectiles being ejected from the laptop is entirely consistent with the source of the fire being a thermal runaway reaction that began inside a single cell in the battery pack and then spread heat to other adjacent cells in the pack that sequentially produced the same reaction. Based on the physical evidence, it is the conclusion of FRT experts Krasinski and Litzinger that the flammable gases and projectiles from the battery pack started the fire that consumed the home. During a thermal runaway reaction, the internal battery cell components such as those found inside the closet where the fire began, could have reached temperatures as high 600 ° C (1,100°F), which is more than sufficient to cause combustible materials within the room including the closet to ignite and produce smoke which set off the smoke alarm.

Figure 8 Photograph of debris removed from closet for inspection (source Karasinski).

Figure 9 Closeup showing battery windings in debris removed from closet (source Karasinski).

During thermal runaway reactions, it is common for flammable gases to explode and this can propel internal cell components and remnants of the cell case in all directions consistent with the remnants of one or more battery cells found inside the closet. (See Figures 8 & 9). The results of such explosions are evident in the ruptured cell casings depicted in Figure 5.

What Ms. Marcellin describes when she visualized the projectiles ejected from the laptop was likely the combination of the first cell experiencing thermal runaway and the subsequent thermal runaway reactions from one or more of the subsequent cells within the battery pack and not just the initial thermal runaway reaction in the first cell alone that started the event.

Moreover, for the thermal runaway reactions in multiple cells to be completed in seconds, as conjectured in the Horn report, would require the complex thermal runaway reactions to occur nearly or essentially simultaneously in multiple cells across the battery pack, meaning the initiating event inside each cell would have had to occur at nearly the same instant, something that is highly unlikely. Detailed scientific studies done of similar individual cells undergoing thermal runaway reactions show variations in the length of time for the reaction to begin, the length of time for the reactions to run to completion, as well as the results of the reaction. In all of the cells studied, the runaway thermal reactions of individual cells extended for periods of time lasting many minutes, and in some cases nearly hundreds of minutes. Larsson et al. (2018). Such periods are hundreds if not thousands of seconds, not mere seconds as conjectured in the Horn report.

Thermal runaway reactions in multicell battery packs such as the one involved in this incident, typically begin in a single cell as described above and then progress to other cells in the pack through the heat generated in the first cell experiencing this reaction. This means that the full time for a multi-cell battery pack to complete thermal runaway reactions of multiple individual cells would therefore occur in a cascade of heating events where cells experiencing thermal runaway would heat adjacent cells to thermal run away. Such a series of events would therefore be the sum of the times for each cell (or combinations of cells) to reach thermal runaway and this would necessarily occur over a period of many minutes up to as long as hours and therefore be on the order of hundreds to thousands of seconds. These times are, of course, far longer than the mere seconds as conjectured in the Horn report.

The description of events given by Ms. Marcellin in her testimony is consistent with this type of **prolonged** time to failure and fire. Further, Ms. Marcellin's sworn testimony, the FRT

fire expert reports of Mr. Karasinski and Litzinger, and my analysis of the laptop and battery pack refute the speculation of Dr. Horn that the thermal runaway reaction in the cells of this battery pack was caused by an external heat source. All evidence I have reviewed is consistent with a thermal runaway reaction occurring inside one or two cells inside the battery pack that then caused the thermal runaway of other remaining cells.

Thus, the eye-witness testimony taken together with all the physical evidence disproves Horn's speculation. The fire could not have been raging for over an hour before Carol Marcellin responded to the smoke alarm, the time it has been documented in the Larsson study for such lithium ion battery cells to reach thermal runaway from an external heating source. Further, there is no evidence that the thermal layer caused by the fire ever reached down to the height of the laptop, indeed the evidence of the thermal damage at the fire scene was ended more than a foot above the level of the laptop. Even further, there is also no evidence that the laptop (other than the area immediate of the battery pack) or the other combustible materials near the laptop were ever exposed to such extreme temperatures. Areas of the laptop immediately adjacent to the battery pack were essentially undamaged.

Counter to the external thermal layer hypothesis speculated by Dr. Horn, there were multiple combustible materials depicted in photographs of the armoire located at elevations above the level of the laptop that did not ignite.[1] (See Figures 10 and 11). Moreover, the older

[1] Paper will typically ignite at approximately 233°C (451°F) without an external flame source, depending on configuration.

external monitor which was located at a higher elevation on a shelf directly behind the laptop in the armoire does not show damage consistent with external temperatures in this range.[2] (See

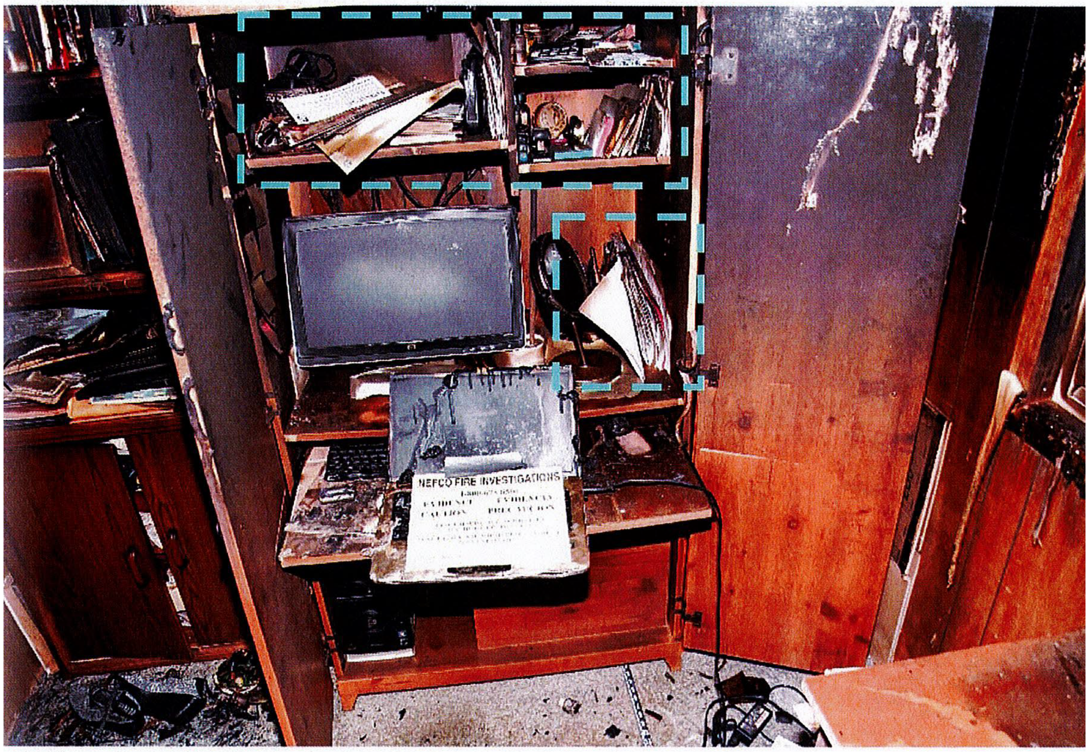


Figure 10 - Photo of armoire and laptop from Myers Report [Figure 19].

Figure 11, closeup of the external monitor where you can still read the control symbols on the bottom right of the monitor).

Not only is there no evidence of uniform damage to the entire laptop consistent with exposure to an external heat source that would be capable of causing thermal runaway in the battery pack, but the battery pack compartment on the bottom of the laptop where the battery pack was inserted does not show uniform thermal damage. As shown above, the left side of this battery pack compartment in Figure 4 was essentially unheated and remains mostly intact with even the labeling remaining undamaged. Conversely, the right side of this compartment shown in Figure 4 is almost entirely destroyed. Nor, for that matter, was there any thermal damage to the

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[2] Plastic, depending on the exact composition, will melt at temperatures ranging from 70°C to 200°C.

bottom of the laptop outside of the immediate area of the battery pack compartment. Thus, all the physical evidence is inconsistent with Dr. Horn's speculation that a large superheated thermal layer enveloped the laptop and heated the cells inside the battery pack to the excessive temperatures required to induce thermal runaway.

Conversely, the evidence is entirely consistent with cell-level thermal runaway occurring internally from an overcharge, overvoltage and/or overtemperature condition in a cell on the right side of the battery pack as depicted in Figure 4, beginning a chain reaction that resulted in the explosion of two of the cells and destruction of the inner contents of two additional cells, leaving the remaining two cells largely intact.

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Figure 11 - Closeup picture of the Armoire and Laptop from Karasinski Report [Figure 55].

The US Consumer Product Safety Commission has identified over 25,000 overheating or fire incidents involving more than 400 types of lithium-battery-powered products over a five year period.[3] In recognition of the risks of fire caused by overcharge, overvoltage and overtemperature conditions posed by lithium-ion batteries, battery manufacturers have agreed to a standardized Smart Battery Systems Specification to require certain safety features incorporated into battery management systems for lithium-ion batteries to prevent these conditions.[4] HP's specification for the battery pack in the subject laptop requires a gas gauge chip that provides these safety features to shut down power to the battery pack when overcharge, overvoltage or overtemperature conditions occur and specifies that such gas gauges must comply with this Smart Battery Systems Specification industry standard. (HP01378). All HP witnesses agree that the battery pack in the subject laptop did not have any of these safety features enabled. There is no scientific evidence to support any cause of the thermal runaway that occurred in in this battery pack other than overcharge, overvoltage or overheating while charging. For the reasons stated above, the speculation that the thermal runaway reaction was caused by an unknown external fire from an unknown source in an unknown location lacks any supportable evidence or scientific validity and was not arrived at to a reasonable level of scientific certainty based on any acceptable methodology.

II. "FIXED VALUE RESISTOR" THEORY

Donald Galler, P.E., speculates on page 19 of his report that a manufacturer of counterfeit battery packs could have utilized a fixed value resister in place of the thermistor that was intended to be connected directly to the motherboard of the subject laptop and this would have

[3] Yuan, et al., (2020).
[4] https://sbs-forum.org/specs/sbdat110.pdf

defeated any system designed by HP to shut off power to the battery pack if no signal was received from the intended thermistor designed to be communicating directly with the motherboard.

Mr. Galler does not say the battery pack in the laptop when the fire occurred utilized such a fixed value resister, as there is no evidence to support this speculation. His speculation that had HP designed its safety system to prevent charging of the battery pack if no signal was received from the thermistor designed to be connected to the motherboard is just that, speculation. He has presented no factual basis for the claim that any manufacturer of counterfeit battery packs has ever utilized such a fixed value resistor device to defeat such a safety system. Moreover, the reason counterfeiters fail to install safety devices in the first place is to reduce the cost of manufacture of the counterfeit battery packs to make them more attractive to consumers seeking replacements. Mr. Galler has not provided any data establishing that installing such a fixed value resister would produce a significant manufacturing cost savings to the counterfeiter.

As discussed in the Texas Instruments Application Report, SLUA346A – July 2005 (ref. 5 in my initial report), the more expense needed to defeat authentication systems designed into the host device, the less incentive is provided to counterfeiters to produce compatible replacement batteries for such systems. Had HP designed its system in the subject laptop to recognize a counterfeit battery pack that lacked a functioning thermistor to communicate the battery pack temperatures to the motherboard, under Mr. Galler's theory, to defeat such a system a counterfeiter would have incurred the additional expense to initially analyze the HP laptop to determine whether or not such a system was installed, discover how it was implemented, and then design, optimize, test, manufacture, and then implement a device or devices to defeat the HP authentication system . For instance, this safety authentication system could be programmed to

shut off power to the battery pack not only if it failed to receive *any* signal from the thermistor in the battery pack, but if it failed to receive a varying signal communicating temperatures within the expected operating range of the battery cells. If that were the case, a single resister sending a constant unvaried signal would not defeat the system. However, the main point is, the counterfeiter would need to figure all of that out and then design a specific system to defeat it, all of which would cost money and encourage the counterfeiter to move on to manufacture replacement batteries for a simpler system.

Mr. Galler has provided no factual support for what the cost to the counterfeiter would be to first discover how such a system could be defeated and to then install a device or devices to defeat it. It would likely be cheaper for the counterfeiter to install the thermistor required in the original battery pack, which if functional, would have prevented an overtemperature condition from occurring. Mr. Galler has failed to identify any real-world application of his speculation demonstrating any counterfeit manufacturer ever utilizing such a device.

Dated: January 3, 2024

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